EXHIBIT F

Macroscopical and Microscopical Examination of Tape Evidence

1 Introduction

Based on their discriminating power, visual, microscopical, and physical examinations are the logical initial steps in a forensic tape analysis. Numerous studies have demonstrated that appearance features and physical characteristics can differentiate tapes of the same general type. Specific characteristics of tape fabrication that allow for this discrimination are discussed in detail in Johnston's book (2000). Physical examinations of interest to the forensic scientist regarding tapes are covered in both Smith (2007) and the Scientific Working Group for Materials (SWGMAT) tape subgroup guidelines.

2 Scope

This procedure outlines and describes the macroscopical, microscopical, and physical examinations of a variety of tape specimens commonly submitted as evidence to the Chemistry Unit of the FBI Laboratory.

3 Principle

Macroscopical and microscopical observations as well as physical measurements are perhaps the most important steps in a forensic tape analysis. The examiner or chemist assesses what type of tape is present for examination, unravels or separates the tape specimen(s) as needed, determines if an end match exists between specimen(s), observes how much suitable material is available for testing, and makes additional visual comparisons between tape specimens of similar type as appropriate. The examiner or chemist considers all of these factors and determines the best analytical approach. This process may be the only examination conducted in a comparison analysis if exclusionary features or individualizing characteristics between samples are revealed during this initial evaluation.

Physical measurements such as widths and thicknesses and observations regarding component colors, distinctive markings on the backing (e.g., calendaring marks), and the arrangement and number of yarns in the fabric reinforcement of some types of tape (e.g., duct tape or gaffer's tape) are all evaluated and documented.

4 Specimens

The most common types of tape evidence analyzed in crime laboratories are duct tape, vinyl electrical tape, and packaging tape. Masking tape, strapping tape, and gaffer's tape are also encountered. Tape evidence is routinely submitted as a tangled mass, in strips from ligatures or gags, or still adhered to various substrates. These substrates include such items as clothing, paper, plastic, or components of an improvised explosive device.

5 Equipment/Materials/Reagents

a. Stereo microscope (6X to 50X magnification) with appropriate light source (such as an annular ring light or fiber optic light)

b. Compound microscope (35X to 400X magnification) with appropriate light source

c. Ultraviolet light with long wavelength (~365nm) source

d. Cold source (liquid nitrogen in a porcelain dish, freezer, or equivalent)

e. Heat source (air dryer or heat lamp)

f. Scalpel handles with blades

g. Single edge razor blades

h. Probes (steel, tungsten, wood or Teflon)

i. Micrometer, 0-1" range, digital or vernier scale accurate to 0.0001", or equivalent

j. Stainless steel ruler with metric (1 mm) and English (1/64") graduations

k. Tweezers

l. Glass microscope slides

m. Disposable wipes

n. Cotton swabs

o. Thin-layer chromatography glass chamber, or equivalent, with lid

p. Acetone (Reagent grade)

q. Hexane (Reagent grade)

r. Methanol (Reagent grade)

s. Chloroform (Reagent grade)

t. Eyedropper bottles and/or disposable pipettes

u. Heavy-gauge transparency film or KAPAK® tubular rollstock

v. Munsell Neutral Value Scale and Soil Color Charts available from the Macbeth Division of Kollmorgen Instruments Corporation, New Windsor, NY

w. Polarizing light microscope with a quarter wave or full wave plate

x. Digital camera

y. Digital microscope

6 Standards and Controls

Not applicable.

7 Calibration

Not applicable.

8 Sampling

Refer to the PPSU SOP *General Approach for Tape Casework* for guidance in determining an appropriate sample selection plan.

9 Procedure

Examination begins with an evaluation of the sample(s) upon receipt. If the tape evidence is received as a tangled mass or a series of overlapping strips, each piece is separated, flattened, and arranged on heavy-gauge transparency film (or equivalent clear, colorless plastic sheets) for comparison of physical properties. Vinyl plastic document protectors are not suitable due to the presence of volatile plasticizers within their matrix, which can migrate into the adhesive layer of the tape; however, clear plastic evidence storage bags (e.g., KAPAK®) are acceptable.

If the items are suitable for examination, a detailed accounting and description of the tape specimens is recorded. Written descriptions, sketches, photography, or other imaging methods are used to capture both macroscopical and microscopical characteristics and observations. A flow chart of the physical measurements and observations described below for a tape examination is provided in Figure 1. The discrimination value of a tapes' physical characteristic's depend on the type and condition of the tape. Therefore, the order of the examinations depicted in Figure 1 is left to the discretion of the examiner.

1. Tape specimens that are wadded together or overlapped require special attention in order to free the adhesive layers. The following sample treatments may be used to aid in the separation. The use of these methods should be arranged in order to minimize alteration of the sample (e.g., adhesive removal, fabric or backing distortion, or damage to the free ends).

    a. Gently heat the tape with an air dryer while applying tension on opposite sides of the wadded area in order to reduce the tack of the adhesive. This process should be done gradually to allow the tape to be manipulated without being torn or distorted.
    b. Fill a porcelain dish or crucible with liquid nitrogen and immerse the tape for approximately one minute. If freezing does not enable quick and easy unpeeling, a second attempt should be made before trying another separation technique. The tape may also be placed in a freezer (inside a container under proper seal and appropriately labeled) overnight.

c. If the tape is so entwined as to risk damage or tearing with the methods mentioned above, suspend the mass in a thin layer chromatography tank along with approximately 100 mL of chloroform (in two 50 mL beakers placed at opposite ends of the tank with the wadded tape in between). Cover the appropriately-labeled tank, and place it under proper seal in a fume hood for several hours or overnight. After being subjected to the solvent-saturated atmosphere, the tack of the adhesive should be reduced to facilitate separation and flattening of the pieces.

d. Under a vented fume hood, apply an appropriate solvent drop wise to the edges of a wadded area or adhesive/substrate interface and gently pry the edges apart. A mild solvent (e.g., hexane for rubber-based adhesives or acetone for acrylic-based adhesives) should be used initially. If a more aggressive solvent is required, chloroform may be used. Moderate heating may be helpful in conjunction with the solvent application.

2. Observe the separate components of the tape specimen using both the unaided eye and a stereo microscope with 6X to 50X magnification.

a. Record observations regarding the adhesive color. Provided color attributes have not been obscured by environmental effects or previous forensic examinations (e.g., weathering or latent fingerprint processing), differences will quickly disassociate items of evidence. Important distinctions include a clear, colorless adhesive versus a black adhesive on vinyl electrical tape, or a tan adhesive versus a clear, colorless adhesive on brown packaging tape. Duct tape adhesive color comparisons can be facilitated using the matte version of the Munsell Neutral Value Scale or Soil Color Charts.

b. Record observations describing the tape backings such as color, degree of gloss, texture, or, fabrication markings. If necessary, clean the tape backing with a mild solvent (e.g., methanol or water) and a cotton swab. The backing of a duct tape should be cleaned in order to determine the layer structure. This is accomplished by freezing the backing to ensure rigidity, taking a cross-section with a single-edged razor blade, and viewing the cross-section in transmitted light with a compound microscope.

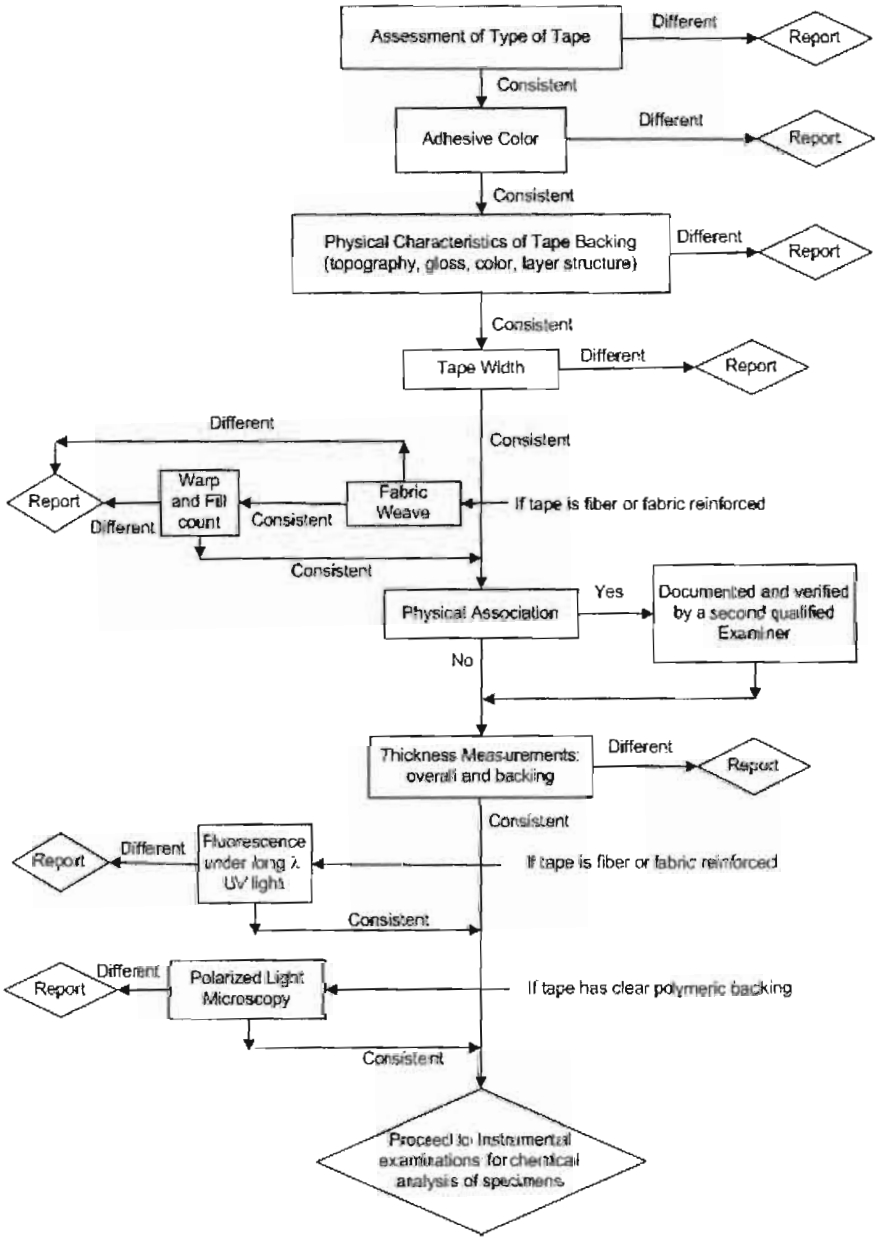

Figure 1. Basic Approach to a Physical Examination of Tape Specimens

3. Tape width is another point of comparison between specimens. Take a minimum of three measurements along a representative sample, and record these values to the nearest $^{1}/_{64}$" or 0.5 mm. If a measurement may be an outlier, perform the Grubbs' test to determine if that value should be eliminated. Some tapes will permanently deform when stretched, torn, or stressed. Therefore, width measurements should only be compared when it can be reasonably ensured that the tape specimen(s) have not been severely distorted.

4. Tape samples containing fiber or fabric reinforcement can be differentiated based on several factors: yarn count, yarn composition and construction, and fabric weave. To expose the fabric or fiber reinforcement, rubber-based adhesive can be removed with hexane or chloroform; acrylic-based adhesives can be removed with acetone.

   a. Determine the weave pattern and a general description of the warp and fill yarns. Plain weave and weft-insertion are common examples of fabrics encountered in duct tape samples. The weave and yarns may be depicted in the case notes as a description, sketch, photocopy, or photograph.

   b. Determine the number of yarns in a one square inch section of the tape in both the machine direction (m.d., warp) and cross direction (c.d., fill). If the sample is large enough, determine the warp and fill count at a minimum of three locations. In general, a variation of ±1 yarn in either or both directions is expected within a tape specimen. If the sample is limited in size, the yarn count in the machine and/or cross direction can be calculated from a measurement on an area less than one inch. Record the area measured in the case notes.

   c. Determine and record if yarns in the machine and/or cross directions fluoresce under UV exposure at ~365 nm.

5. Examine tape evidence for possible end matches between specimens.

   a. With the aid of a stereomicroscope, observe the tear pattern from the backing and adhesive sides of both specimens to determine if an end match is plausible.

   b. If the backing is distorted or folded over and adhered to the adhesive layer, carefully straighten it out to restore the edge. This may be facilitated with the use of tweezers, heat, or mild solvent.

c. Determine if there are individualizing characteristics such as a defect in the backing or in the fabric reinforcement that extends across the fracture. The beginning and end point of the defect must be apparent on both specimens to ensure that it is not continuous along the entire roll of tape.

d. If the tape has fiber or fabric reinforcement, use an appropriate solvent to remove enough of the adhesive layer to expose the reinforcing yarns. Ensure that the yarns in the machine (and if present, fill) direction line up along the fracture.

e. Depending on the type of tape, fabrication marks such as striations from extruders or embossed marks from calendar rolls may align across fractured edges providing additional features to corroborate an end match.

f. Any end matches must be documented with descriptive notes.

i. End matches between specimens that link a suspect to a crime scene or to a victim must be confirmed and documented in the case notes by a second examiner also qualified in the same category of testing. They must also be photographed. The imaging method must include a measuring scale. In the case of fabric-reinforced tapes, documentation may also include a diagram or map of the severed yarns to illustrate each complementary pair of warp yarns rejoining along a common margin at the fracture.

ii. Unless deemed necessary based on case details, all remaining end matches (e.g., within Q associations, Q specimens from the same crime scene) need not be confirmed by a second qualified examiner. Therefore, this step can be disregarded in Figure 1. Furthermore, one specimen may be taken as representative of the reconstructed strip for the remaining examinations.

6. Using a micrometer, determine the total overall thickness and backing thickness of the tape specimen(s). Rubber-based adhesives can be removed with hexane or chloroform; acrylic-based adhesives can be removed with acetone. Take a minimum of three measurements along a representative sample, and record these values to the nearest 0.00005". If a measurement may be an outlier, perform the Grubbs' test to determine if that value should be eliminated. Some tapes will permanently deform when stretched, torn, or stressed. Further, the adhesive might be contaminated or partially removed in a used tape specimen. Therefore, thickness measurements should only be compared when it can be reasonably ensured that the tape specimen(s) have not been severely distorted, degraded,

or contaminated.

7. If the backing is a clear, colorless polymeric film, affix a sample to a glass microscope slide oriented with the machine direction parallel to the edge of the slide. Observe the tape under cross polars and compare the extinction angle and birefringence colors.

8. If all physical attributes and measurements are consistent between specimens being compared, proceed with instrumental examinations according to the applicable Paints and Polymers Subunit standard operating procedures.

10 Decision Criteria

a. If physical characteristics of two specimens being compared differ, examinations cease and it is reported that the specimens are different.

b. If the width difference between two specimens being compared is ≤ 1.0 mm (2/64"), they are considered consistent with one another. If the difference between the two specimens is >1.0 mm (2/64"), perform the two sided student t-test to determine if the difference is statistically meaningful.

c. If the yarn count between two specimens being compared is ±1 yarn in either or both directions, the specimens are considered consistent with one another.

d. If the difference between the mean thicknesses of two specimens being compared is ≤ 10% of the larger mean, they are considered consistent with one another. If the difference between the two specimens is > 10%, perform the two sided student t-test to determine if the difference is statistically meaningful.

e. Decision criteria for a tape end match are described in section 9, step 5.

11 Calculations

1. The mean, $\bar{x}$, of n measurements is given by:

$$\bar{x} = \frac{\sum x_i}{n}$$

2. The standard deviation, s, of n measurements is given by:

$$s = \sqrt{\frac{\sum_i (x_i - \bar{x})^2}{(n-1)}}$$

3. Grubbs' test:

$$G = \frac{|suspect\ value - \bar{x}|}{s}$$

where s is calculated with the suspect value included.

The critical values for G can be found in *Statistics and Chemometrics for Analytical Chemistry*. If the calculated value of G exceeds the critical value, the suspect value is rejected.

4. t-test (assuming that the samples are drawn from populations with equal standard deviations):

$$t = \frac{(\bar{x}_1 - \bar{x}_2)}{s\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

where s is calculated from:

$$s^2 = \frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{(n_1 + n_2 - 2)}$$

and t has $n_1 + n_2 - 2$ degrees of freedom.

The critical values for t can be found in *Statistics and Chemometrics for Analytical Chemistry*. If the absolute value of the calculated value of t exceeds the critical value of t, the means are significantly different.

5. Alternatively, these calculations can be performed using statistical computer software, such as Microsoft Excel.

12 Uncertainty of Measurement

Not applicable.

13 Limitations

a. Sample size and condition may preclude conducting certain examinations.

b. Color, width, or thickness assessments may be affected by sample condition.

c. In the absence of an end match between specimens, source identification back to a particular roll of tape is not possible.

14 Precautionary Statements

a. Precautions must be taken to minimize the potential for damage to the sample, particularly with respect to tearing or distorting the ends of the tape.

b. Contamination or degradation of the adhesive layer can affect total overall thickness measurements.

15 Safety

Take standard precautions for the handling of chemicals (including liquid nitrogen) and sharps. Use universal precautions when handling potentially biohazardous materials. Refer to the current revision of the *FBI Laboratory Safety Manual* for guidance.

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0	06/21/06	New document that replaces previous document also titled *Macroscopic and Microscopic Examination of Tape Evidence*.
1	09/30/09	Changed the sampling plan guidelines and updated references.
2	02/27/12	Updated microscopic and macroscopic to microscopical and macroscopical where appropriate throughout document. Added digital microscope to section 5. Changed "sampling" plan to "sample selection" plan in Section 8. Clarified end match procedure in Section 9, step 5f. Changed thickness measurement decision criteria in Section 10. Updated references.

Approval

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